

**Total Bycatch Estimate
of Loggerhead Turtles
(*Caretta caretta*)
in the 2004
Atlantic Sea Scallop
(*Placopecten magellanicus*)
Dredge Fishery**

by

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Errata
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Two changes are needed to Reference Document 05-12 regarding information about fishing vessels operating with general category permits in the sea scallop dredge fishery during 2004. Neither change affects the total estimated bycatch of sea turtles in the fishery.

The changes are as follows:

1. Under Methods, pg 3, the statement, "Vessels fishing under a General Category permit are subject to DAS restrictions in open areas, and to a possession limit of 400 lbs scallops/day inside the Access Areas (NEFMC 2004)," should be changed to:
"Vessels fishing under a General Category permit are subject to a possession limit of 400 lbs scallops/trip inside and outside the Access Areas (NEFMC 2004)."
2. Under Methods, pg 3, the statement, "In 2004, trip length for Limited Access vessels averaged 8 days/trip, with vessels fishing approximately 160 dredge hours/trip, while General Category vessels averaged 1-2 day trips, fishing an average of 50 dredge hours/trip," should be changed to:
"In 2004, trip length for Limited Access vessels averaged 8 days/trip, with vessels fishing approximately 160 dredge hours/trip, while General Category vessels averaged 1-2 day trips, fishing an average of 7 dredge hours/trip."

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Table of Contents

Abstract	v
Introduction.....	1
Methods	2
Observer Coverage.....	3
Observed Turtle Takes.....	4
Commercial Fisheries Data.....	4
Model Development.....	4
Turtle Bycatch Model	7
Results	8
Turtle Bycatch Model	8
Total Bycatch of Turtles	9
Discussion.....	9
References.....	12

List of Tables

Table 1.	Turtle bycatch in the 2004 Mid-Atlantic scallop dredge fishery.	13
Table 2.	Observed versus predicted turtle takes from an examination of candidate models	14
Table 3.	Variables examined in an analysis of factors affecting sea turtle bycatch in the Mid-Atlantic scallop dredge fishery during 2004.....	15
Table 4.	Variables affecting bycatch rates of turtles in the 2004 Mid-Atlantic sea scallop dredge fishery.....	16
Table 5.	Total bycatch estimate of turtles from June-November 2004 in the Hudson Canyon Controlled Access Area and outside this area in the Mid-Atlantic sea scallop dredge fishery	17

List of Figures

Figure 1.	Sea scallop management areas under the rotational area management system in 2004.....	18
Figure 2.	Observed and commercial trips in the Mid-Atlantic sea scallop dredge fishery, June to November, 2004	19
Figure 3.	Observed turtle interactions in the Mid-Atlantic sea scallop dredge fishery during 2004	20
Figure 4.	Partial fits for the general additive model (GAM) of sea turtle bycatch with area (“dat”) and depth as covariates, showing the relationship estimated by a smoothing spline	21
Figure 5.	Predicted bycatch rates of turtles in the mid-Atlantic sea scallop dredge fishery, June to November 2004	22

ABSTRACT

From June to November 2004, an estimated 180 (C.V.=0.37, 95% C.I.=65-319) loggerhead sea turtles (*Caretta caretta*) interacted with sea scallop (*Placopecten magellanicus*) dredge gear in the Mid-Atlantic region. Several changes occurred in the scallop dredge fishery during 2004 which may have reduced the probability of encountering a turtle in scallop dredge gear. These include voluntary use by some fishermen of a chain mat, designed to exclude turtles from entering the dredge bag. In addition, rotational closures and gear restrictions implemented under the Atlantic Sea Scallop Fishery Management Plan also shifted the distribution of fishing effort.

This study used Generalized Additive Model fitting techniques to examine environmental factors and gear characteristics influencing the bycatch rate of turtles in 2004, including an examination of several candidate models to describe turtle interactions with the fishery over 2003-2004. The candidate model that best described the 2004 observed takes was based on the 2004 data alone, rather than on a pooled dataset from 2003-2004. In estimating total bycatch, rates were stratified based on depth, and whether trips fished inside or outside the Hudson Canyon Access Area (HCAA). Highest bycatch rates occurred outside of the HCAA, in depths between 54 and 70m.

INTRODUCTION

Over the past several years, fisheries observers have documented loggerhead sea turtle (*Caretta caretta*) interactions with Atlantic sea scallop (*Placopecten magellanicus*) dredge gear in the Mid-Atlantic region, from Long Island, New York to Cape Hatteras, North Carolina. During 2001-2002, estimated bycatch of turtles in the Hudson Canyon Access Area (HCAA) and Virginia Beach Access Area (VBAA), two formerly closed areas that had reopened for scallop fishing, was 169 animals (Murray 2004). In response to the observed bycatch in these access areas, observer coverage of the scallop dredge fleet increased in 2003 to cover the broader Mid-Atlantic region, from New York to North Carolina. During 2003, an estimated 749 loggerhead interactions occurred in the Mid-Atlantic sea scallop dredge fishery, including 122 interactions in the HCAA (Murray 2004a). During 2003, turtle interactions occurred from July through October.

Several changes occurred in the scallop dredge fishery during 2004 which may have influenced the probability of encountering a turtle in the dredge gear. First, some fishermen began using, voluntarily, a modified dredge designed to exclude turtles (DuPaul and Smolowitz 2004). This modified dredge was equipped with a “chain mat”, in which a series of tickler chains and up and down chains are strung in a grid-like configuration from the chain sweep to prevent turtles from entering the dredge bag. Industry trials using the grid revealed that the chain mat could successfully exclude turtles from entering the bag with relatively small reductions in the scallop catch.

Other regulatory changes were implemented in the scallop fishery in 2004 which changed the spatial and temporal distribution of fishing effort. The scallop dredge fishery is now managed under a rotational area program, which is a combination of areas closed to scallop fishing, access areas which allow a limited amount of fishing, and open areas subject to days-at-sea (DAS) allocations (Figure 1). The Elephant Trunk Closed Area, located south of the HCAA and offshore from Delaware Bay (Figure 1), was closed to fishing on 23 July 2004 and is to remain closed until March 2007 (NEFMC 2004). This may have caused some fishermen, who may otherwise have fished elsewhere, to use their DAS in this area prior to July 23rd. During 2003, almost all of the turtle interactions in this area occurred during October.

On 2 November 2004, two formerly closed areas on Georges Bank were opened for fishing on a limited basis (NEFMC 2004a). Fishermen were given the option of taking 1 trip into the Nantucket Lightship Area, or 2 trips into Closed Area II, or taking extra DAS in open areas of the Mid-Atlantic prior to November. Many fishermen opted to take the extra days in the Mid-Atlantic, which could have increased effort in the areas and times when most turtle takes have occurred in the past.

New scallop dredge gear restrictions were implemented in the middle of 2004. On 23 July 2004, the minimum mesh size for the dredge twine top was increased from 8 to 10" in all areas, and the minimum chain bag ring diameter for vessels fishing in the Hudson Canyon Access Area was increased from 3.5 to 4" (NEFMC 2004). These gear restrictions may have caused fishermen to fish more heavily prior to July 23rd in anticipation of having to alter their gear. Again, this would have reduced effort during the period when most turtle takes occurred in 2003.

This paper identifies factors that influenced the bycatch rate of loggerhead turtles in the Mid-Atlantic sea scallop dredge fishery in 2004, and provides an estimate of the bycatch of turtles in this fishery in 2004.

METHODS

The 2004 fishing year for the U.S. commercial Atlantic sea scallop fishery occurred from 1 March 2004 to 28 February 2005 in the Gulf of Maine, Georges Bank, and Mid-Atlantic regions. This analysis deals solely with fishing trips operating in the Mid-Atlantic region from Long Island, NY to Cape Hatteras, NC (approximately 41°15'N/70°00'W to 36°06'N/70°00'W) from 1 June to 30 November 2004. This region does not include trips operating in the Nantucket Lightship Area, located east of 70°00'W. It is assumed here that there are no turtle interactions in the scallop fishery in the Georges Bank and Gulf of Maine regions; thus, sea scallop dredge effort in these regions was excluded from the analysis. The scallop fisheries in these regions operate north of the general range of loggerhead turtles (~41°N latitude as a northern limit; Shoop and Kenney 1992). In 2004, there were no observed takes in the sea scallop dredge fishery operating on Georges Bank, although observer coverage (% of observed trips/VTR trips)

in this region from September-November was less than 2%, with most of the coverage occurring in November after the Closed Area II and Nantucket Lightship Access Areas opened. No observer coverage occurred in the Georges Bank region June-August 2004.

Vessels in the U.S. scallop dredge fishery operate under either a General Category fishing permit or a Limited Access permit. Vessels fishing under a General Category permit are subject to DAS restrictions in open areas, and to a possession limit of 400 lbs scallops/day inside the Access Areas (NEFMC 2004). Limited Access vessels may catch up to 18,000 lbs/trip of scallops inside the Access Areas, and are allowed a limited number of trips in the Access Areas based on their permit category. From June to November 2004, approximately 99% of dredge hours in the HCAA was due to Limited Access vessels, and 1% to General Category vessels. The majority of Limited Access vessels (75%) use 2 dredges, while 85% of General Category vessels use a single dredge. In 2004, trip length for Limited Access vessels averaged 8 days/ trip, with vessels fishing approximately 160 dredge hours/trip, while General Category vessels averaged 1-2 day trips, fishing an average of 50 dredge hours/trip. From June to November 2004, General Category fishing effort (i.e. dredge hours) in the Mid-Atlantic increased 136% compared to 2003.

Observer Coverage

During June-November 2004, fishery observers observed 5% (% observed dredge hours/VTR dredge hours) of the total commercial sea scallop dredge effort in the Mid-Atlantic. Coverage in the HCAA was 6%, and 4% outside (see text table below and Figure 2).

Observer Coverage in the 2004 Atlantic Sea Scallop Dredge Fishery

Area	Total Observed Dredge Hours	Total VTR Dredge Hours	Observer Coverage
Hudson Canyon	7036.3	109222.1	0.06
Outside	10654.5	257998.2	0.04
Total	17690.8	367220.3	0.05

In this analysis, the boundaries of the HCAA are based on the boundaries prior to it being overlapped by the Elephant Trunk Closure Area. A total of 172 trips were observed, of which 45 (26%) were General Category trips. Sixteen of the observed trips used scallop dredges equipped with chain mats.

Observed Turtle Takes

Eight turtle interactions were observed in the Mid-Atlantic scallop dredge fishery during 2004 (Table 1). Only 1 of these (12%) occurred in the HCAA. Two takes occurred in June (25%), 3 in August (38%), 1 in September (12%), and 2 in October (25%) (Figure 3). Two of the 8 (25%) animals were released alive and uninjured, 5 were injured (63%), and 1 (12%) was fresh dead. The length of the animals captured in the gear, measured from the notch to the tip of the carapace, ranged from 71 to 170 centimeters.

One additional turtle was captured during July when an observer was off-watch; the observer was not collecting information on the haul. This turtle was not included in the count of turtles used to calculate bycatch rates, although it is subsumed in the 2004 bycatch estimate.

Commercial Fisheries Data

Vessel Trip Reports (VTR) from scallop dredge fishermen operating in Mid-Atlantic waters from Long Island, NY to Cape Hatteras, NC from June to November 2004 were used in this analysis. Number of dredge hours from trips without coordinate positions (4.5%) was prorated across bycatch strata based on the percentage of dredge hours in these strata from trips with known coordinates.

Model Development

A Generalized Additive Model (GAM) was used to explore the relationship between turtle bycatch (the response variable) and gear and environmental covariates.

GAMs differ from Generalized Linear Models (GLMs) in that smooth functions replace the linear predictors in GLMs (Hastie and Tibshirani, 1990). Smooth functions, or “smoothers”, summarize the trend of a response measurement as a function of multiple predictors (Hastie and Tibshirani, 1990) and do not assume any particular form of parametric relationship between the response and explanatory variables (Guisan et al. 2002). Smooth curves, in particular, help characterize the effect of continuous explanatory variables on the response.

A logistic regression was used to model the probability of turtle bycatch per dredge hour (GAM function with binomial family, SPLUS 6.1). A dredge hour is the amount of time, in hours, that a single dredge is towed through the water. A vessel pulling 2 dredges for 1 hour each, therefore, would have 2 dredge hours of effort. The model can be written as:

$$\log(turtles / dredgehr) = \beta_0 + f_1x_1 + f_2x_2 + \dots f_ix_i \quad (1)$$

where f_i is a smooth function, and x_i a predictor variable describing environmental, gear, or fishing characteristics.

To model the bycatch rate (i.e. adjusting for varying time spans), the logarithm of days fished becomes an offset variable with a coefficient set to 1.0 (Allison 1999). Thus the model can be rewritten as:

$$\log(turtles) = \log(dredgehr) + \beta_0 + f_1x_1 + f_2x_2 + \dots f_ix_i \quad (2)$$

A forward stepwise selection method was used to determine the best fitting model (StepAIC function, SPLUS 6.1). Criteria for retaining a factor in the model were based on the Akaike Information Criterion (AIC), which is defined as:

$$AIC = -2 \log(L(\theta | y)) + 2K \quad (3)$$

where $\log(L(\theta | y))$ is the numerical value of the log-likelihood at its maximum point and K is the number of estimable parameters (Venables and Ripley 1999). Thus the AIC is equivalent to a likelihood ratio test penalized by the number of parameters in the model. From a series of candidate models, the model with the lowest AIC is considered to be the best fit among the models considered (Burnham and Anderson, 2002).

Initially, the model used to predict bycatch in 2003 was evaluated for its appropriateness in fitting the 2004 data. The goodness-of-fit of the model was evaluated by comparing, in each stratum, the observed number of takes to the predicted number of takes from the model using a Chi-square test. Applying the 2003 parameter estimates, or predicted bycatch rates, for each temperature stratum to the 2004 data resulted in significant differences ($p < 0.001$) in the observed versus predicted number of takes in 2004 (Table 2). Thus, the model used to estimate the bycatch of turtles in the 2003 Mid-Atlantic sea scallop dredge fishery did not accurately describe factors affecting bycatch in this same area during 2004. This suggested that other factors may be influencing the bycatch rates in 2004, warranting a separate examination of the 2004 data. As a result, the 2003 and 2004 data were pooled to better understand factors influencing the bycatch rates of turtles over these two years.

Using the 2003-2004 pooled data, year and sea surface temperature were the only factors which reduced the AIC in the model, indicating that a difference existed in bycatch rates between 2003 and 2004 with respect to the variables examined (Table 3). To investigate why the bycatch rates differed between years, the stepwise modeling process was rerun with the pooled data for the HCAA only, and again for the area outside the HCAA. For the HCAA data, year and sea surface temperature were the only factors that reduced the AIC in the model. For the outside area, only sea surface temperature reduced the AIC, suggesting that a year effect was due to differences in the HCAA between 2003 and 2004.

Two preliminary models were fit to the pooled data; one that included a temperature and year effect, and another which included a temperature effect and a year and area interaction effect. These models were compared to a model developed for estimating total bycatch in 2004 using only the data from 2004 (Table 2).

Turtle Bycatch Model

Of the four candidate models considered for estimating bycatch in 2004, the best-fitting model was that fit to the 2004 data alone. A forward stepwise selection method was used, and criteria for retaining a variable in the model (Table 3) were based on the Akaike Information Criterion (AIC). Bycatch rates were stratified based on factors which lowered the model AIC.

Any continuous variables which lowered the AIC were categorized into bins, using the smooth curves from the GAM as a guide. Variable values were grouped according to whether they had a positive or negative influence on the bycatch rate (i.e., the group explained more or less than the average bycatch rate). Fitting the model with categorized variables was necessary to expand the bycatch rates to derive a total estimate of the bycatch of turtles in scallop dredges. The final model was evaluated by comparing the predicted turtle takes to the observed turtle takes in each stratum.

The coefficient of variation (C.V.) and 95% confidence interval (C.I.) for each stratum-specific bycatch rate was estimated by bootstrap resampling (Efron and Tibshirani, 1993). The resampling unit was a single trip, with all of its associated dredge hauls. Replicate bycatch rates were generated based on the best-fitting GLM model, by sampling with replacement 1000 times from the original data set. The C.V. was defined as the standard deviation of the bootstrap replicate bycatch rate in a stratum divided by the mean bycatch rate for that stratum.

The total estimated turtle bycatch in each stratum was calculated as the product of predicted bycatch per dredge hour (i.e., the predicted bycatch rate) for that stratum and the total number of dredge hours by the sea scallop dredge fishery in that stratum:

$$\frac{\sum \text{Predicted Bycatch}_i}{\sum \text{Dredge Hour}_i} \times (\text{Total Dredge Hours})_i \quad (4)$$

where i = stratum. Total bycatch was the sum of the stratified bycatch estimates.

A C.V. and 95% confidence interval for the total bycatch aggregated over all strata was also calculated from the bootstrap replicates. Total estimated bycatch was first calculated by stratum:

$$B_s^U = R_s^U E_s \quad (5)$$

where

B_s^U is the expected bycatch in stratum s in bootstrap replicate U ,

R_s^U is the bycatch rate for stratum s in bootstrap replicate U , and

E_s is the VTR effort in stratum s .

The total bycatch for bootstrap replicate U , B^U , is then given by:

$$B^U = \sum_s B_s^U \quad (6)$$

The C.V. and 95 % C.I. of the total bycatch estimate was computed for B^U .

RESULTS

Turtle Bycatch Model

Factors influencing the bycatch rates of loggerhead turtles in the 2004 were depth zone, and whether trips occurred inside or outside of the HCAA (Table 4, Figure 4). Depth was binned into three categories: a) <54m, b) ≥54 to <70m, and c) 70 – 100m. Bycatch rates were predicted, therefore, in six strata. The predicted number of takes perfectly matched the observed number of takes in each stratum, indicating the model fit the data well (Table 2).

Highest bycatch rates occurred outside of the HCAA, in depths between 54 and 70m (Table 5, Figure 5). Lowest bycatch rates occurred in waters deeper than 70m.

Total Bycatch of Turtles

The total estimated bycatch of sea turtles from June to November 2004 in the Mid-Atlantic sea scallop dredge fishery is 180 turtles (C.V.=0.37, 95%CI = 65-319) (Table 5). Of these, 17 (9%) occurred in the HCAA, and 163 (91%) occurred outside. Two of the eight observed turtles were released alive and uninjured, implying a 25% minimal survival rate. Hence, using this observed survival rate, of the 180 interactions, an estimated 45 turtles are considered to have been returned to the water alive and uninjured.

DISCUSSION

Unlike 2003, bycatch rates of turtles in the Mid-Atlantic sea scallop dredge fishery differed between the HCAA and outside this area. During June-November 2004, bycatch rates were lower inside the Hudson Canyon Access Area than outside this area. Only 1 turtle interaction was observed in the HCAA compared to 16 the previous year, despite an 18% increase in observed dredge hours in the HCAA in 2004. Both inside and outside the HCAA, turtle bycatch rates were influenced by depth zone fished, with highest rates in both areas occurring in the intermediary depth zone, from 54-70m.

During 2004, observer coverage in the HCAA in waters deeper than 70m was 8.0%, versus 1.6% coverage in this same depth zone in 2003. The increased observer coverage may have reflected scallop dredge fishing effort shifting into deeper waters in the HCAA in 2004 (see text table below). During June – November 2004, the bycatch rate of turtles in waters deeper than 70m was zero. In the HCAA during this time period, 25% of the total sea scallop dredge effort occurred in waters deeper than 70m, versus 1% the previous year. Shifts in fishing effort during 2004 into waters 70m and deeper may have prevented turtle interactions from occurring.

Percentage of VTR Scallop Dredge Hours by Depth Zone in the HCAA

	<54m	54-69m	>=70m
2003	32%	67%	1%
2004	7%	68%	25%

Turtle interactions in 2004 may have been influenced by a combination of depth zones and sea surface temperature. In previous years, sea surface temperature (SST) was a significant predictor of turtle bycatch rates in the Mid-Atlantic (Murray 2004, 2004a). From an analysis of turtle interactions during 2001-2002 within the Hudson Canyon area alone, both SST and depth affect the probability of interacting with a turtle (Murray 2004). Observer coverage in 2004, both inside and outside the HCAA, was adequate relative to temperature ranges examined in 2003 (see text table below).

Percent Observer Coverage by Sea Surface Temperature Range and Area in the 2003 and 2004 Atlantic Sea Scallop Dredge Fishery

		HCAA	Outside
2003	<22°	7.8%	1.5%
	>=22°C	12.3%	1.2%
2004	<22°	5.2%	3.6%
	>=22°C	8.2%	5.2%

The small number of takes in 2004 relative to the number of dredge hours examined may have precluded the detection of significant effects. The shift of fishing effort into deeper waters in 2004 may also have affected the average SST in which the fleet operated. Changes in fishing effort across SST and depth zones in 2004 relative to 2003 may have influenced whether a turtle interaction occurred.

Areas of highest predicted bycatch rates were located to the north and south of the Hudson Canyon Access Area. The closure of the Elephant Trunk area to the south of Hudson Canyon may help reduce bycatch of turtles in future years, depending on the location of displaced fishing effort. Moreover, use of the turtle chain mats is currently proposed to be mandatory for sea scallop dredge vessels operating in the Mid-Atlantic

during May through November¹. Both of these measures may help reduce total bycatch of turtles beyond 2004.

In this analysis it was difficult to discern whether chain mats influenced the bycatch rate of turtles, due to the few number of chain mat trips observed in 2004 and to the nature of interactions that may occur with this gear modification. This analysis suggests that bycatch rates differ by depth and area only, and so vessels fishing with or without a chain mat in each of these strata are assumed to have the same bycatch rate. No turtle interactions occurred on the 16 observed trips where vessels used chain mats. It is unknown what proportion of the commercial fleet voluntarily used chain mats in 2004. If chain mats reduce the bycatch rate of turtles, the estimate provided here may be biased high; alternatively, if interactions with the chain mat still occur but are not observed, the estimate provided here may be biased low.

The rare nature of turtle interactions in 2004 (~1 observed take: 1,000 observed dredge hours) made it difficult to identify variables significantly affecting bycatch rates, even with a reduced number of variables used in the selection process. The small changes in AIC relative to the null model suggested that even area and depth, the two variables selected for a best fit, were not strong predictors. Still, pooling 2004 data with 2003 data was not appropriate due to the differences in factors affecting bycatch across the two years. To examine whether bycatch estimates were sensitive to the 2004 modeling approach, total bycatch was also estimated using a simple ratio method. In this method, observed turtle takes per month were multiplied by total fishing effort per month from June to November. The total bycatch estimate generated from the ratio estimate was within a 2% range of the estimate generated from the model used in this analysis.

Since 2001, SST and depth have influenced turtle bycatch in the Mid-Atlantic scallop dredge fishery, albeit the effect of each is more pronounced in different years and in different geographic regions (Murray 2004, 2004a). The complex nature of scallop dredge fishing effort under a rotational area management system, coupled with changes in the distribution of observer effort, turtle abundance, and oceanographic conditions, make it difficult to interpret changes in bycatch rates from one year to the next. To date, the models developed to estimate bycatch fit well for individual years; however, more

¹ Proposed Rule, FR 70: 30660-30666, 27 May 2005.

work is needed in developing a single, predictive model to help forecast turtle interactions in any year.

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Table 1: Turtle bycatch in the 2004 Mid-Atlantic scallop dredge fishery. Trip letters signify a unique trip. ‘Cas’ = Hudson Canyon Controlled Access Area; ‘Out’=Outside this Area. ‘LA’ = Limited Access Fishing Permit. The lengths of two animals were estimated (“est.”) by the observer, and not measured directly.

Event	Trip	Month	Depth (m)	Area	SST (°C)	Dredge Frame Width (ft)	Tow-speed (kn)	No. of Dredges /Haul	Vessel Length (ft)	Permit Plan	Chain Mat Yes=1 No=0	Animal Condition	Animal Length (notch to tip, cm)
1	A	Jun	52	Out	20.0	13	4.6	2	74	LA	0	Alive	170.0 (est.)
2	B	Jun	59	Out	21.7	10	4.5	1	75	LA	0	Injured	80.0
3	C	Aug	65	Cas	23.9	10	4.9	1	45	LA	0	Dead	70.9
4	D	Aug	67	Out	24.8	13	4.4	2	86	LA	0	Injured	74.0
5	E	Aug	67	Out	25.0	10	4.7	1	72	LA	0	Injured	80.0
6	F	Sep	50	Out	23.3	15	4.6	2	80	LA	0	Injured	92.0
7	G	Oct	56	Out	19.4	13	4.5	2	86	LA	0	Injured	75.0 (est.)
8	G	Oct	56	Out	20.6	13	4.5	2	86	LA	0	Alive	107.0

Table 2: Observed versus predicted turtle takes from an examination of candidate models. A chi-squared goodness-of-fit test tests the null hypothesis that there is no difference in observed and predicted takes. Observer coverage (% observed dredge hours/VTR dredge hrs) in each strata is also shown. The “preferred” model was based solely on 2004 data and reflects the bycatch rate stratification used in this analysis.

Model	Strata	Observed Takes in 2004	Predicted Takes in 2004 from Model	Chi-Squared P value	Observer Coverage
2003 Model with a Temp Effect Only	<22°C	4	3	P<<0.001	0.03
	>=22°C	4	35		0.06
2003-04 Pooled Model with a Temp and Year Effect	2003, <22°C	2	5	P=0.006	0.03
	2003, >=22°C	20	18		0.03
	2004, <22°C	4	1		0.03
	2004, >=22°C	4	7		0.06
2003-04 Pooled Model with a Temp Effect, and a Year and Area Interaction	2003, <22°C, Outside	1	2	P=0.369	0.02
	2003, >=22°C, Outside	5	4		0.01
	2003, <22°C, HCAA	1	3		0.08
	2003, >=22°C, HCAA	15	14		0.12
	2004, <22°C, Outside	4	2		0.04
	2004, >=22°C, Outside	3	5		0.05
	2004, <22°C, HCAA	0	0		0.05
	2004, >=22°C, HCAA	1	1		0.08
Preferred Model with an Area and Depth Effect	Hudson Canyon, Depth < 54m	0	0	P=1.0	0.07
	Hudson Canyon, Depth >=54m and <70m	1	1		0.06
	Hudson Canyon, Depth >=70m	0	0		0.08
	Outside, Depth < 54m	2	2		0.04
	Outside, Depth >=54m and <70m	5	5		0.04
	Outside, Depth >=70m	0	0		0.02

Table 3: Variables examined in an analysis of factors affecting sea turtle bycatch in the Mid-Atlantic scallop dredge fishery during 2004. Percentage of observed and VTR hauls for categorical variables are shown, and the range of values for continuous variables. The same variables were examined for pooled datasets with the addition of a YEAR variable.

Variable	Definition (% observed hauls or range)	VTR (% hauls or range)
Sea Surface Temperature	Range: 6.7-26.6 °C	6.7-26.7 °C
Depth	Range: 4 – 81m	5 – 110m
Latitude Range	37-37.99°N (14%) 38-38.99°N (40%) 39-39.99°N (40%) 40-40.99°N (6%)	(12%) (39%) (36%) (13%)
Presence/Absence of a Chain Mat	Presence (4.5%) Absence (95.5%)	Not available on VTR logs
Inside/Outside Hudson Canyon Access Area	Inside (40%) Outside (60%)	(28%) (72%)
Permit Plan	Limited Access (98%) General Category (2%)	(85%) (15%)
Tow speed	Range: 3.1-5.9 knots	Not available on VTR logs
Year (for pooled data only)	2003 (36%) 2004 (64%)	(47%) (53%)

Table 4: Variables affecting bycatch rates of turtles in the 2004 Mid-Atlantic sea scallop dredge fishery. “Area” indicates whether a trip was inside or outside of the Hudson Canyon Access Area.

Model	Residual Deviance	AIC	$\Delta AIC (AIC_{\text{model}} - AIC_{\text{null}})$
Null (offset only)	131.32	133.32	
Null + Area	128.41	132.41	-0.9
Null + Area + s(Depth)	120.49	132.15	-1.2

Table 5: Total bycatch estimate of turtles from June-November 2004 in the Hudson Canyon Controlled Access Area and Outside this area in the Mid-Atlantic sea scallop dredge fishery. Although trips may fish in each of the respective depth zones, only 1 trip is assigned to each depth category.

Area	Depth Zone	Predicted Bycatch Rate (turtles/dredgehr)	Total Observed Dredgehrs	Total VTR Dredgehrs	Total Observed Trips	Total VTR Trips	Bycatch	Observer Coverage (% Dredghrs observed)	CV	95% CI
Hudson Canyon										
	<54m	0.00007	541.0	7815.6	9	42	1	0.07		0-4
	>=54 and <70m	0.00022	4343.3	74919.7	27	353	16	0.06		0-54
	>=70m	0.00000	2152.0	26486.8	12	155	0	0.08		0-0
Total			7036.3	109222.1	48	550	17	0.06		
Outside										
	<54m	0.00035	5659.9	143156.7	82	3579	50	0.04		0-115
	>=54 and <70m	0.00103	4909.5	110390.6	38	676	113	0.04		22-238
	>=70m	0.00000	85.1	4450.89	4	39	0	0.02		0-0
Total			10654.5	257998.2	124	4294	163	0.04		
Grand Total			17690.8	367220.3	172	4844	180	0.05	37.3%	65-319

Figure 1: Sea scallop management areas under the rotational area management system in 2004. Open areas are those outside the bounds of the management areas.

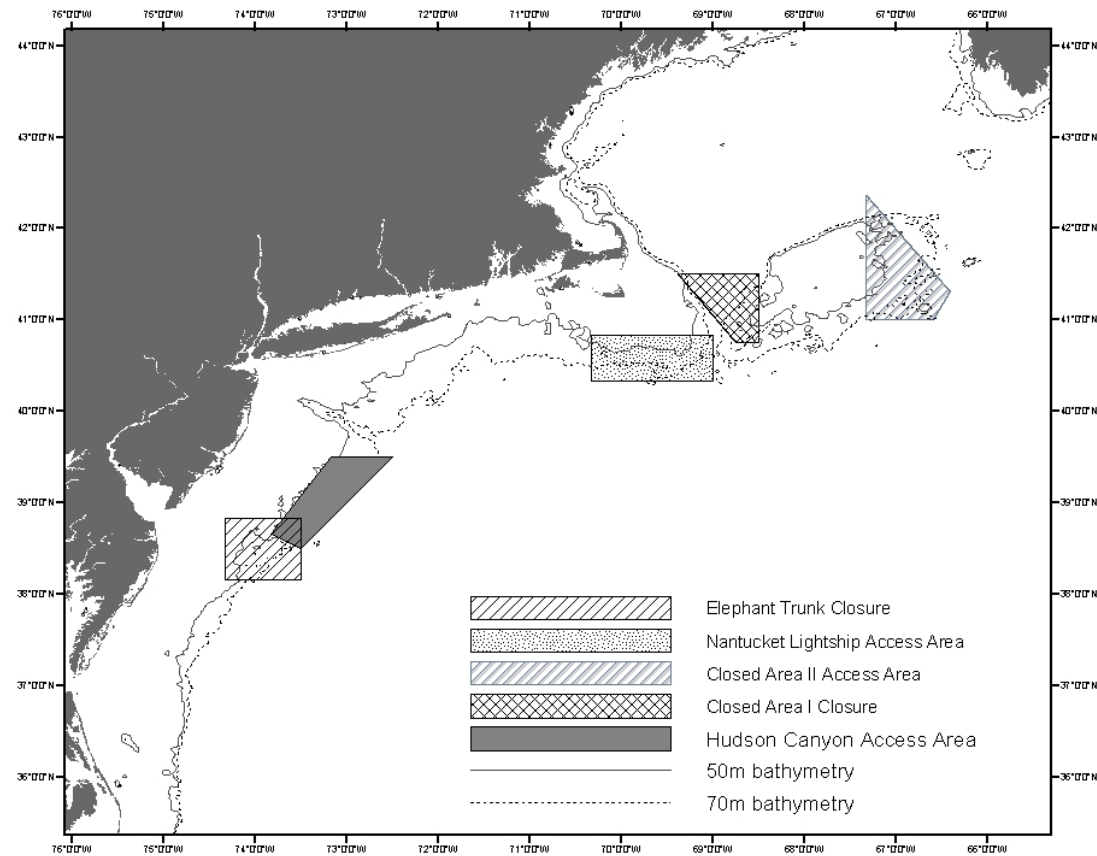


Figure 2: Observed and commercial trips in the Mid-Atlantic sea scallop dredge fishery, June to November, 2004.

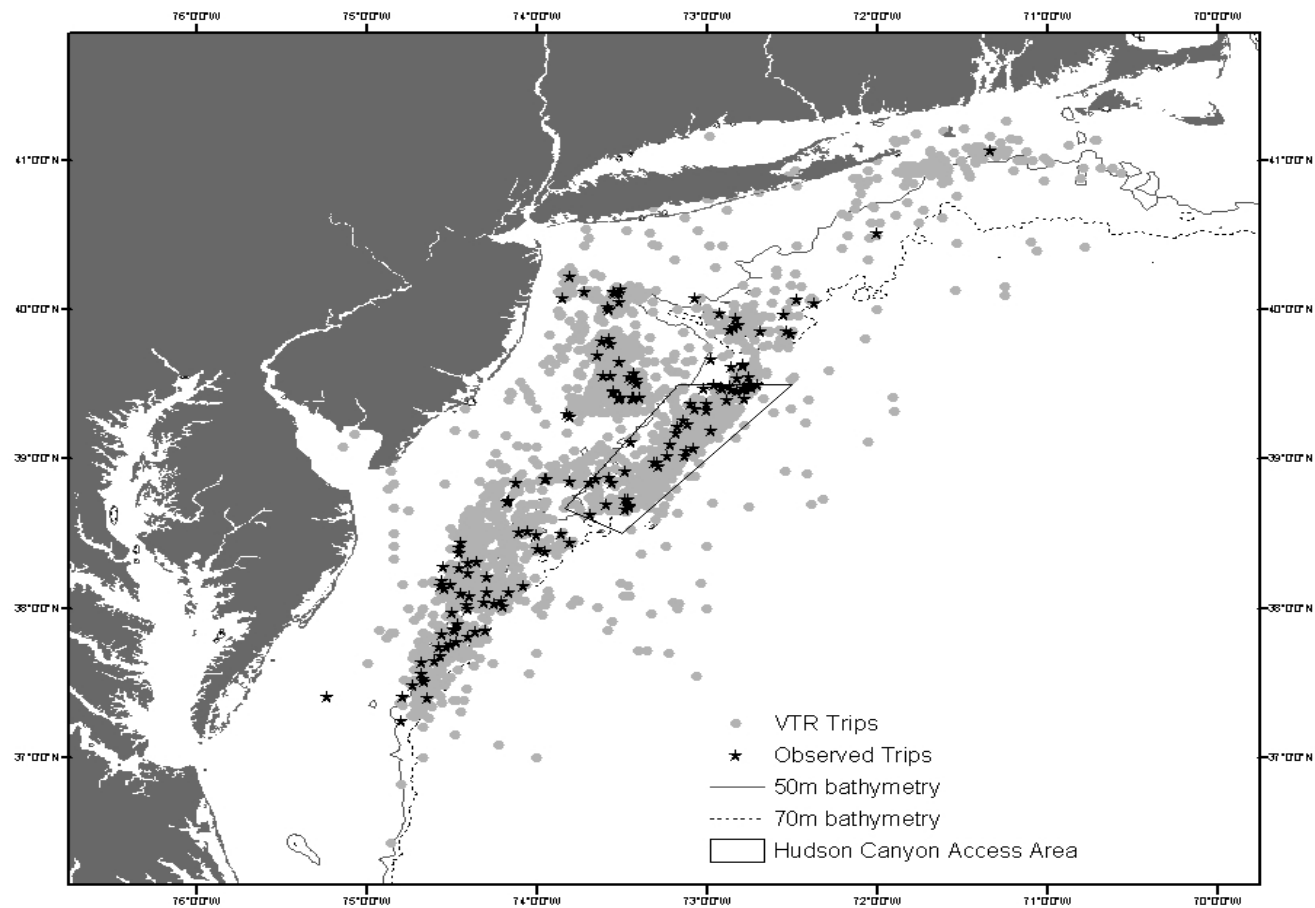


Figure 3: Observed turtle interactions in the Mid-Atlantic sea scallop dredge fishery during 2004.

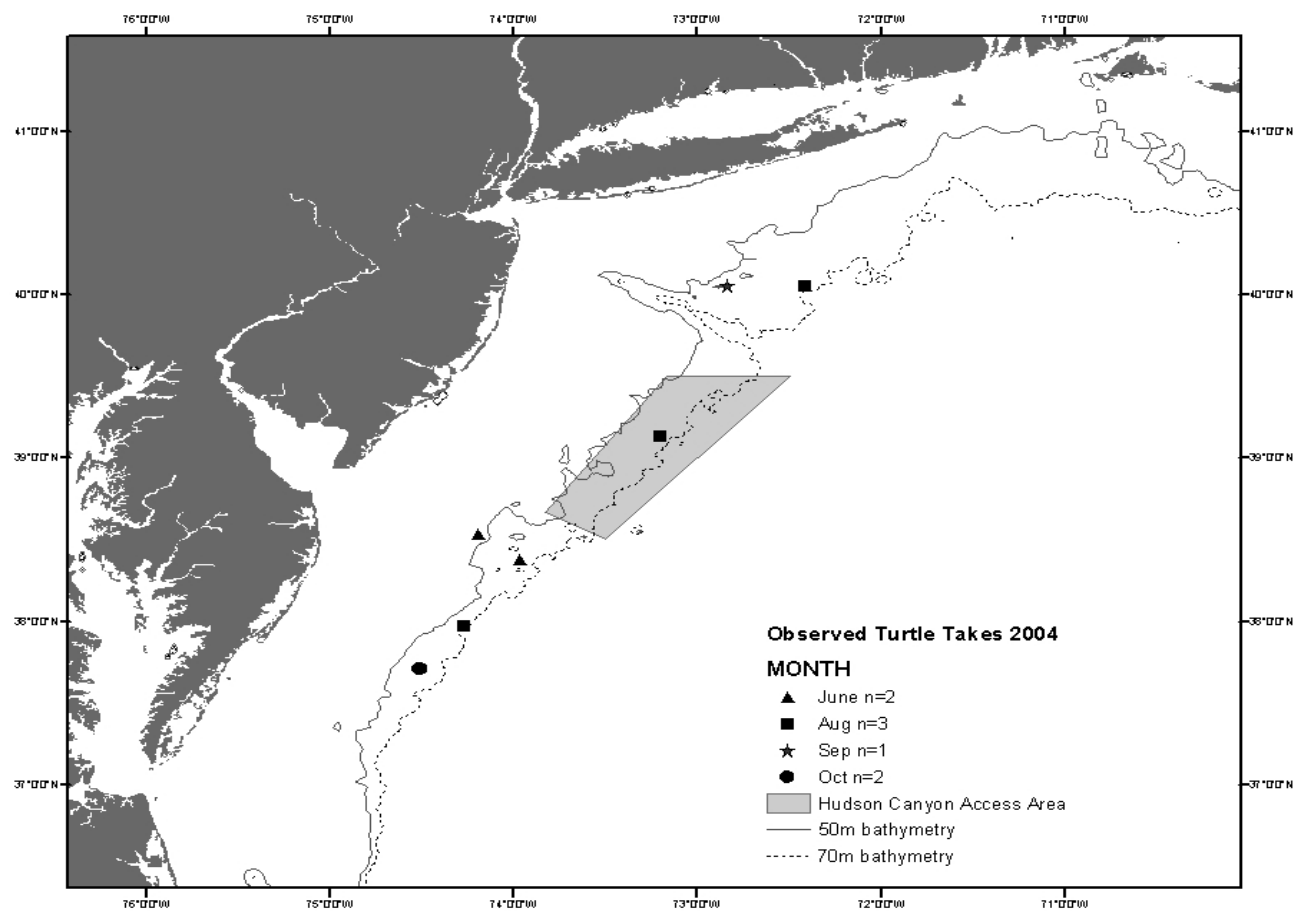


Figure 4: Partial fits for the general additive model (GAM) of sea turtle bycatch with area (“dat”) and depth as covariates, showing the relationship estimated by a smoothing spline. Curves explain the effect of each variable on sea turtle bycatch per dredge hour. ‘Out’ indicates outside the Hudson Canyon Access Area (HCAA), and ‘Cas’ indicates inside the HCAA. Areas outside the HCAA, and depths between 54 and 70 m, have a higher than average bycatch rate.

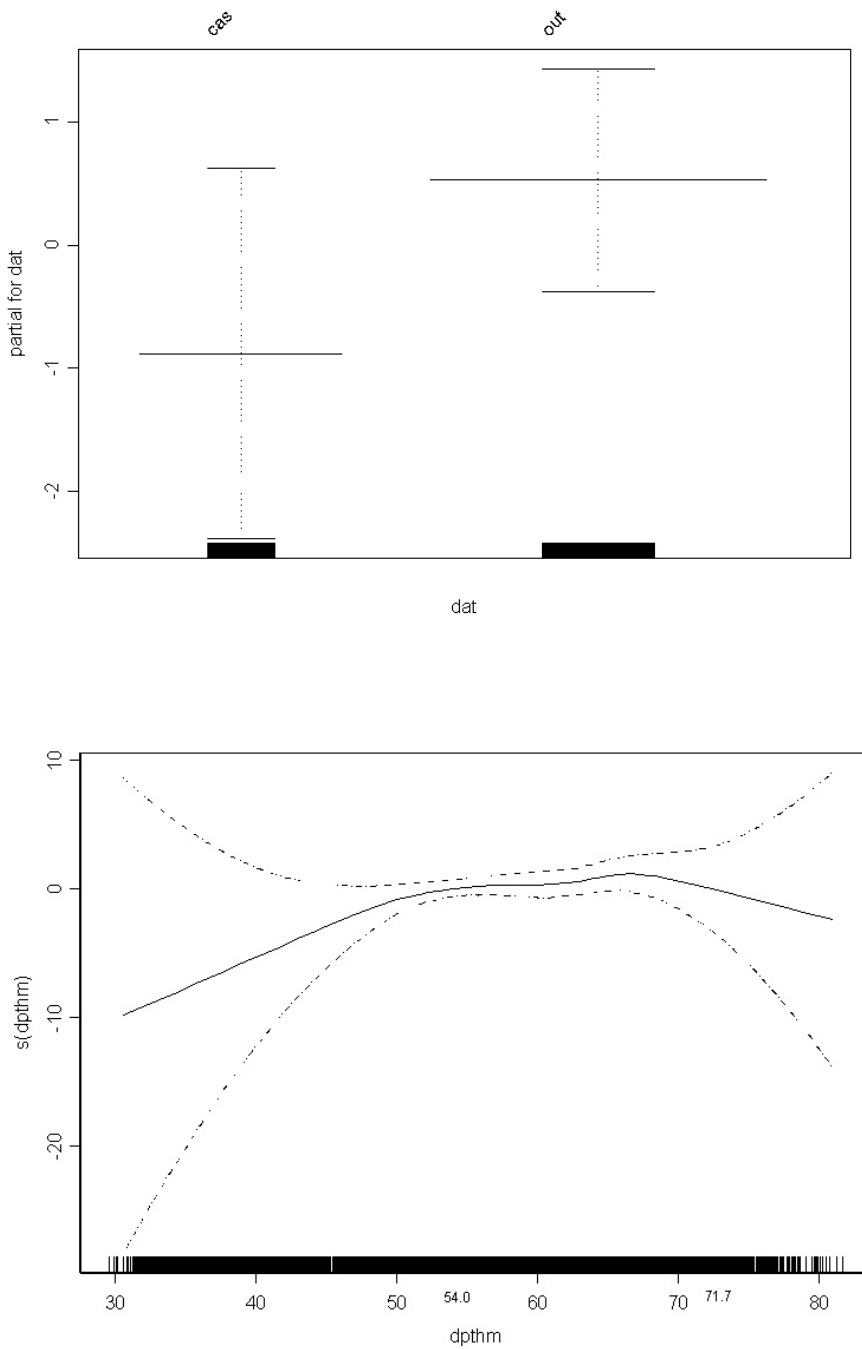
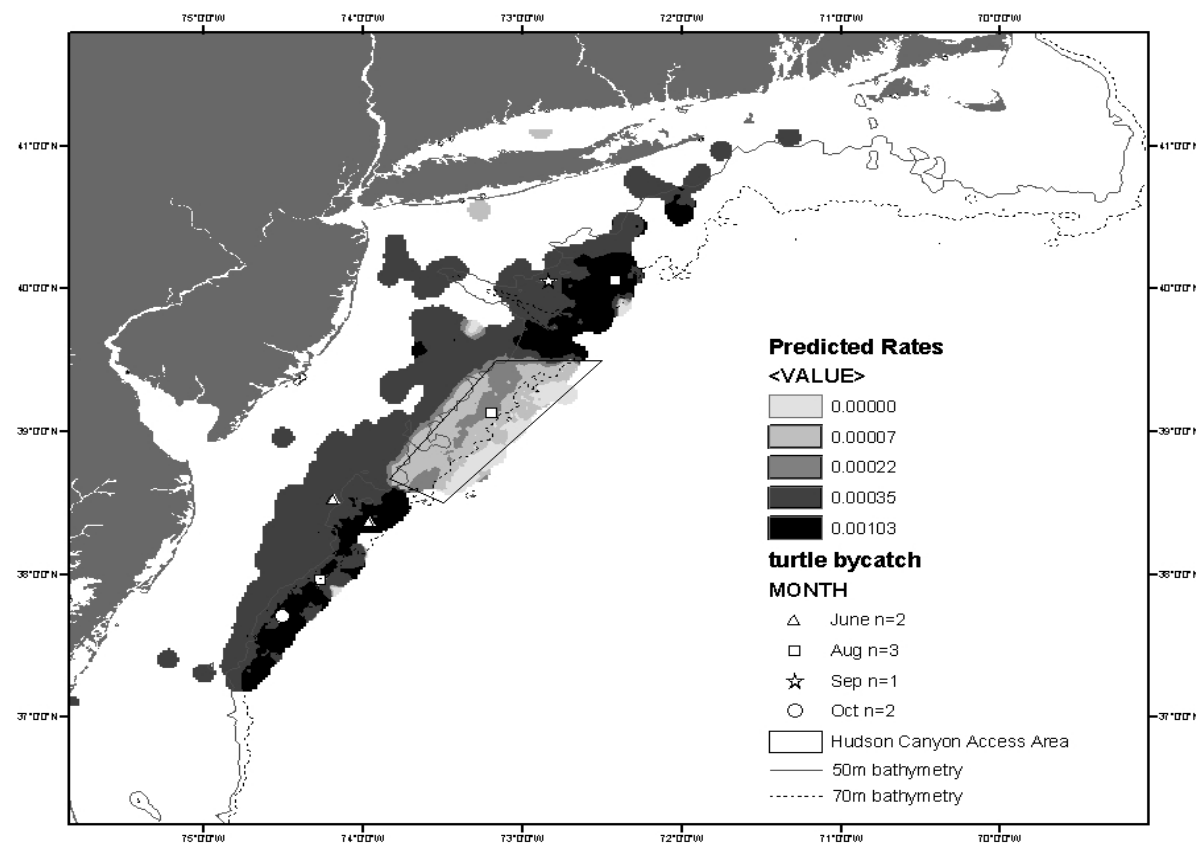


Figure 5: Predicted bycatch rates of turtles in the Mid-Atlantic sea scallop dredge fishery, June to November 2004.



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